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IoT Meets Caregivers: a Healthcare Support System in Assisted Living Facilities

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Abstract. This paper presents a system that exploits the synergy between wearable/mobile technology and smart caring environments to support caregivers in Assisted Living Facilities (ALFs) for persons with physical and cognitive disabilities. In particular, this healthcare support system allows caregivers to be automatically alerted of potentially hazardous situations that happen to the inhabitants while these are alone. The design stemmed from six system requirements derived from the results of three focus groups conducted with 30 caregivers of different ALFs in Northern Italy.

Key words: Smart Caring Environments, Assisted Living Facilities, Caregivers, Persons with Disabilities, Ambient Assisted Living

1 Introduction

Ambient assisted living (AAL) and general healthcare support systems have mainly focused on improving the quality of life for people (especially the elderly) in their own homes and on supporting medical staff in structured environments such as hospitals. From a technical standpoint, the potential of IoT technology to enhance or at least to enrich these systems by sensing physiological signals ubiquitously and unobtrusively, is being increasingly recognized.

However, few studies about IoT-based systems aiming at supporting users different than doctors in hospitals or patients in their homes are available in the literature. In particular, papers that describe systems to support caregivers in ALFs[1] for persons with disabilities are very limited, with some significant exceptions such as WearNET [1] and AMON [2] which are available in the literature for almost a decade now. Another exception, more recent and particularly interesting is presented by Borazio et al. [3], which combines wearable and environmental sensing for sleep studies in a non-structured environment.

The objective of this paper is to present the design and preliminary implementation of an IoT system which combines wearable/mobile technologies with

[1] an assisted living facility is a housing facility for persons with disabilities. ALFs ensure health, safety, and well-being conditions for people in situation of dependency due to cognitive or physical disabilities. In these facilities, unlike in hospitals, there are no full-time nurses nor physicians providing medical treatments.

smart caring environments for supporting caregivers that work in ALFs for persons with disabilities. In particular, such a system fulfils six system requirements derived from the results of three focus groups conducted with 30 caregivers of different ALFs in Northern Italy.

2 User Requirements Analysis

At our knowledge, there are no specific design guidelines for healthcare support systems aimed at supporting caregivers that work with persons with disabilities in ALFs. Therefore, the first phase of our study consisted in identifying the needs and concerns that healthcare workers in ALFs have, understanding how they tackle problems and difficulties in their daily work, and how technology can help or support them. To that end, we conducted three 90-minutes group interviews in the form of focus groups, in three different RAFs (*Residenza Assistenziale Flessibile*, an Italian type of ALF). These group interviews were held in Italian and focused on caregivers' daily activities, common problems and desires. Full audio recordings and photos of particular areas and systems of the three ALFs were collected. We interviewed 30 participants, 22 female and 8 male, with different years of expertise. All of them were professional caregivers, working in three RAFs managed by the Cooperativa Frassati[2]. Two of the structures accommodate people with various degree of mental disorders, while the third one houses people with motor impairments. Each RAF hosts around 10 people and assistance is guaranteed 24/7. All the visited RAFs have a backyard, a fully equipped kitchen, a laundry, an infirmary, a living room, a space used as an office by caregivers and single or shared bedrooms for the inhabitants. Based on such data and on relevant related works such as [4] carried out by Morris et al., we extrapolated the system requirements on which we built the system presented in this paper. Common needs emerge from participants, with some minor differences due to the diverse type of disabilities present in the RAFs. In fact, people with motor disabilities perform most of their activities inside the RAF, while many activities carried on by persons with cognitive disabilities are situated outside the house. During the day, two caregivers are always present in the RAF, performing various activities, such as personal assistance or housework. RAF inhabitants can request the assistance of a caregiver by calling her by voice or using buzzers which are in fixed positions around the house. During the night, only one caregiver is present in the RAF, performing some houseworks and running ward rounds. Each caregiver brings with her a cordless phone, multiple keys and, in some cases, her personal smartphone. RAF inhabitants with mental disabilities, unlike those with motor impairments, do not own any technological tool, such as smartphones, tablets, or computers. Caregivers and inhabitants' parents promote this situation, because of the possibility that such objects might be stolen, broken or forgotten outside the RAF.

[2] `http://www.coopfrassati.com/` (last visited on July 20, 2014)

3 Discussion and System Requirements

We propose an unobtrusive and ubiquitous IoT system with wearable/mobile components, for effectively tackling the most relevant and frequent problems of caregivers within RAFs, without compromising the privacy or dignity of the RAF inhabitants. The system focus on one important issue that emerged during the focus groups: the modalities to provide and require assistance. Nowadays they have to call caregivers by voice or using a buzzer which is fixed in some locations inside the RAF. However, there are situations where caregivers cannot hear the inhabitants calls, or where the buzzer is not reachable. In fact, inhabitants may be outside the house, away from caregivers (e.g., in the backyard), or they may have fallen out of the wheelchair unable to use the buzzer. These missed calls are a problem that currently is not tackled, but that caregivers perceive as "really important" since they are not able to timely intervene. Another related problem of the RAFs we visited that we tried to address with our system, is how to monitor the inhabitants while they are alone in order to timely assist them, in case of need. Inhabitants with either mental or physical disabilities may need quick assistance, but may not be able to request it, e.g., they may be in the middle of an epileptic seizure. Until now, the problem has been tackled by running overnight ward rounds to constantly check for potentially hazardous situations, while during the day it has not been tackled at all.

The overall system requirements, elicited from the analysis of the focus groups results, are reported below. Some of them can be also found, in similar formulations, in other related works such as [4].

1. *Detection and notification of potentially hazardous situations.* Caregivers should be alerted when an inhabitant is involved in a potentially hazardous situation, without the need of constantly running ward rounds or using privacy invasive methods (e.g., video recording).
2. *Supporting smart assistance.* Provide the inhabitants with a smart way of requiring the caregivers assistance, without using noisy buzzers. Confirm that the assistance requests are addressed properly by at least one caregiver.
3. *Determining inhabitants presence in sensitive areas.* Some places of the RAF may not be suitable for the inhabitants, so caregivers want to know where they are located.
4. *Support for RAF management aspects.* Caregivers require that if some information system has to be implemented, it must support some management aspects of the RAF as well as the inhabitants routines planning.
5. *Unobtrusiveness.* Caregivers do not want more "objects" to carry around or strange "gadgets" to use, even if they give useful functionalities. Therefore, the system must fade in the background of the daily life in an unobtrusive way.
6. *Hands-free operations.* Caregivers require to have their hands free, for being ready to assist inhabitants as soon as possible, without concerning about the "health" of the device (i.e., they must be resistant to water and shocks).

4 System Design

For meeting the requirements reported in the previous section, we designed a system that monitors RAF inhabitants by measuring and interpreting some of their body signals and environmental conditions to notify the caregivers whether and where their assistance is needed. In general, the system first collects data from all the different sources and process it to obtain an overview of the RAF situation. Then, by interpreting such information, it determines if an inhabitant needs assistance. In the case she does, the system is also in charge of notifying it to the caregivers, for her to be assisted. The caregiver that first reaches the inhabitant, has to turn the notification off to prevent his colleagues to come in vain. The system also is in charge of managing notifications regarding the overall RAF management (req. 4).

Sensors Environmental and wearable sensors are used for measuring the environmental conditions of the RAF and the body signals of its inhabitants, respectively. The former sense ambient light, temperature, and people presence in specific rooms in order to meet the requirement of determining inhabitants presence in "sensitive" areas (req. 3), such as the kitchen or the infirmary. Wearable technology is used because it allows to meet the unobtrusiveness requirement (req. 5). We choose to adopt the wristwatch form factor since watches are ideally located for body sensors [5] and wearable displays. The wearable sensors collect acceleration data that can be processed and analysed for detecting epileptic seizures and falls, which is one of the most important system requirements (req. 1). The wearable devices worn by the inhabitants with adequate cognitive capabilities, have a "call function" that can be used for consciously requesting caregivers' assistance.

Middleware The middleware is in charge of managing the overall system. It receives the environmental and body measures from the sensors, interprets them and determines if a situation that requires the presence of a caregiver is taking place. The middleware does not aim at assessing exactly what is happening with each RAF inhabitant, but its scope is to point the caregivers attention to "suspicious situations" that *might* require their presence. This means that the middleware is not designed to try to accurately detect potentially hazardous situations, such as epileptic seizures, where the consequences of missing one are very serious and are out of the scope of this kind of support. Caregivers required this type of notification since they are already used to this kind of dynamics in RAFs, given that ward rounds work like this, i.e., by checking on someone even if it is not strictly required. Once the middleware determines that the presence of a caregiver is required somewhere, it sends a proper notification to all the caregivers in the RAF.

Notification Devices The devices in which caregivers receive the notifications sent by the middleware could be wearable or mobile. Wearable technology is the most suitable for meeting most of the previous requirements. One of those requirements (req. 6) is that caregivers need to have the hands free the most of the time, therefore a smartphone or a tablet are not appropriate for them. As in the case of the inhabitant sensors, the notification devices use a wristwatch form factor that is preferred by the caregivers that do not want "*another gadget to think about*". Mobile devices can be exploited to satisfy requirement 4. Notification devices should have sound and vibration alerts capable to draw the attention of the caregiver even in noisy environments.

5 Prototype and Preliminary Validation

The designed system was prototyped with reduced functionalities by extending the Dog gateway[3] capabilities to realize the described middleware. We used sensors of presence, temperature, and light intensity for collecting environmental data, and the cost-effective and re-programmable Texas Instruments eZ430-Chronos wristwatch for notifying caregivers and sensing from inhabitants wrists. This smart watch integrates a 96 segment LCD display, a 3-axis accelerometer, sensors of temperature, pressure and a battery voltage, into an affordable device. The only functionality not supported by the eZ430-Chronos is the haptic feedback, so at this stage vibration alerts are not implemented yet. We use a custom firmware extension[4] similar to the one described by De Russis et al. [6]. The interaction between the wearable devices (eZ430-Chronos) and the middleware (Dog) adopts a client-server paradigm. Their communication starts automatically once per minute, or manually when an inhabitant requests the caregiver presence. Each eZ430-Chronos has a unique identifier that is read and stored by the control system to determine with which device is communicating (i.e., who asks for assistance).

The feasibility of the proposed system was verified in the lab and consisted in the deployment of a scaled down version of the overall system. Two volunteers acted like a caregiver and a RAF inhabitant equipped with one eZ430-Chronos wristwatch each. The system encompassed sensors of presence, light and temperature, and the Dog gateway running on a Raspberry Pi[5]. The goal was to verify the correct operation of the notification subsystem either when the assistance is requested from the inhabitants or when it is requested automatically by interpreting sensor data. Two use cases were successfully tried out: *Assistance request from the inhabitant* and *Notification of potentially hazardous situation.* In the first case the volunteer acting as the inhabitant requested the caregiver assistance by tapping on her wristwatch. Dog notified the caregiver providing the name of the inhabitant asking for his help. In the second case, the volunteer acting as the inhabitant moved her arm in such a way that the middleware

[3] an open source gateway for home and building automation, based on the OSGi framework which provides interoperability between different IoT devices (`http://dog-gateway.github.io`).

[4] `http://github.com/poelzi/OpenChronos` (last visited on July 20, 2014)

[5] A credit-card sized computer with 512 MB of RAM, two USB ports and a 100 Mb Ethernet port.

could interpret that something may be wrong and alerted the caregiver. In both cases the system responded in few seconds and the caregiver turned the assistance request off by reaching the inhabitant and tapping a personal code on the inhabitant's watch.

6 Conclusions

In this paper, we present a system that exploits the synergy between wearable/mobile technology and environmental sensing to support caregivers working in assisted living facilities for people with physical or cognitive disabilities. The system requirements stem directly from three focus groups realized with 30 caregivers in Northern Italy. The system has been prototyped and a preliminary validation has been performed, for verifying its technical feasibility. Future work will be expanding the implemented system to effectively detect potentially hazardous situations by autonomously analysing sensor in real RAFs, and experimenting with other type of wearable/mobile devices.

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